Design of a Concentrator with a Rectangular Flat Focus and Operation with a Suspension Reactor for Experiments in the Field of Photocatalytic Water Splitting

ES-FuelCell2014-6546

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DLR

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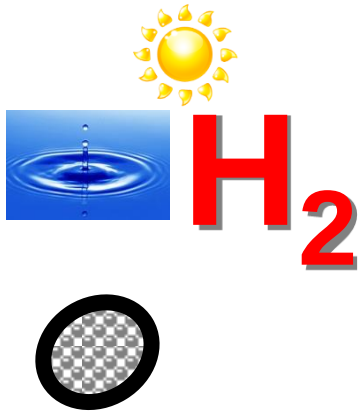
- Introduction
- Design of the solar concentrator
- Qualification of the solar test facility
- Two-chamber suspension receiver
- First experiments in the field of photocatalytic water splitting
- Summary and outlook

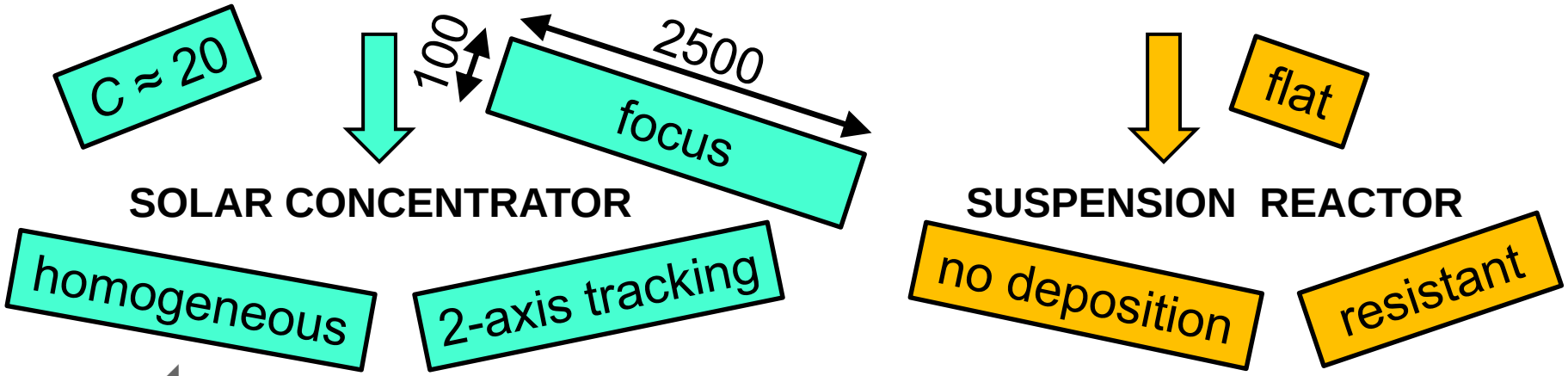
Project HyCats



- Hydrogen production via photocatalytic water splitting

- Design, generation and test of new catalysts
  - Highly efficient and durable
  - Low material costs and long-term availability

- Assessment of new catalysts under concentrated solar radiation



Choice of a Concentrator Concept

C ≈ 20
Risks
Oblong focus
Complexity / size
Flat focus

Solar Concentrator

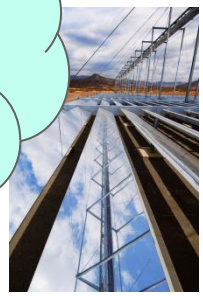
Reflector

Refractor

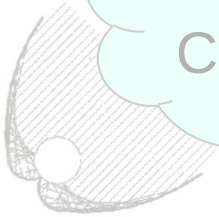
Parabolic Trough

Central Receiver System

Linear Fresnel Collector



Compound Parabolic Concentrator



…

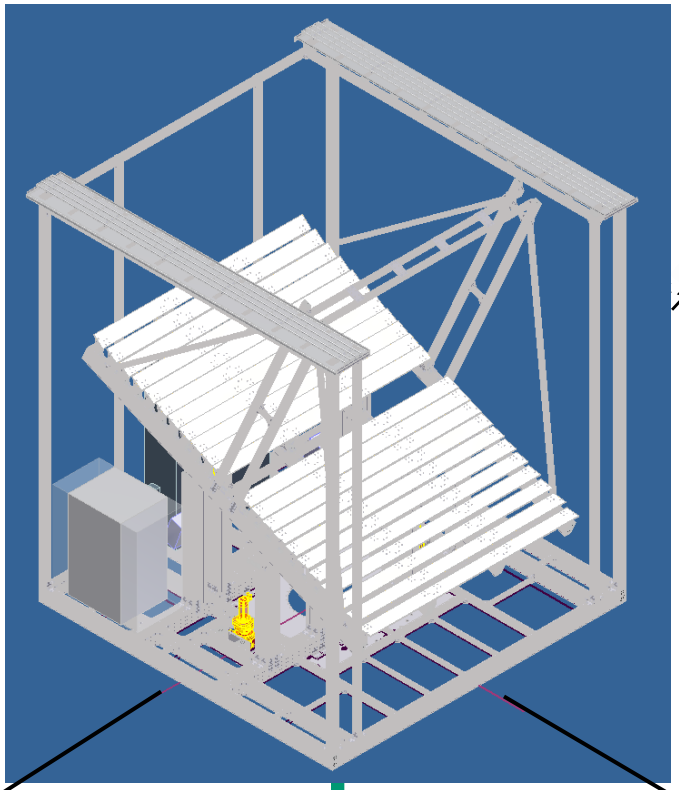
Parabolic Dish

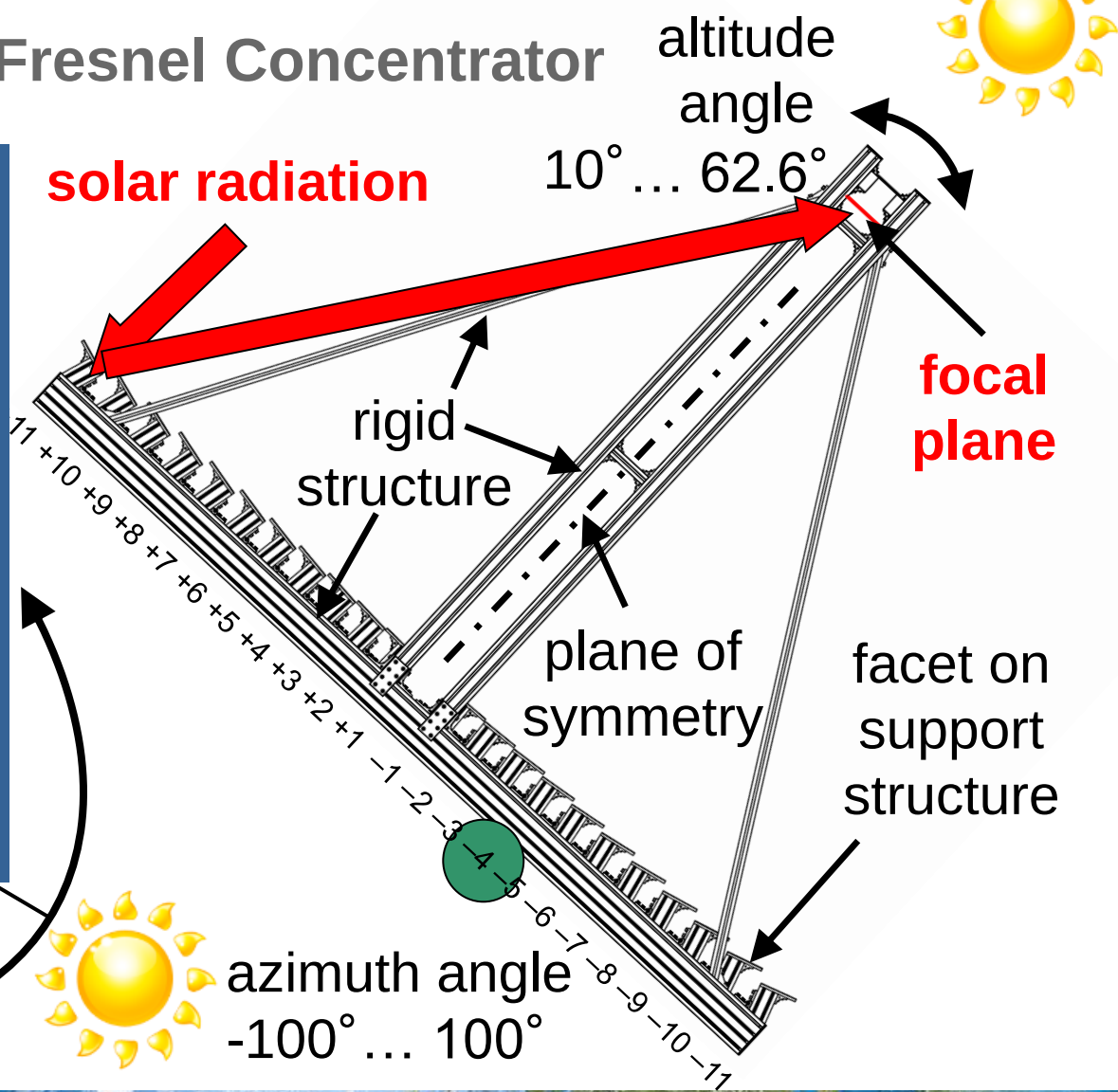
modified concept (ESFuelCell2012-91441)

Solar Furnace

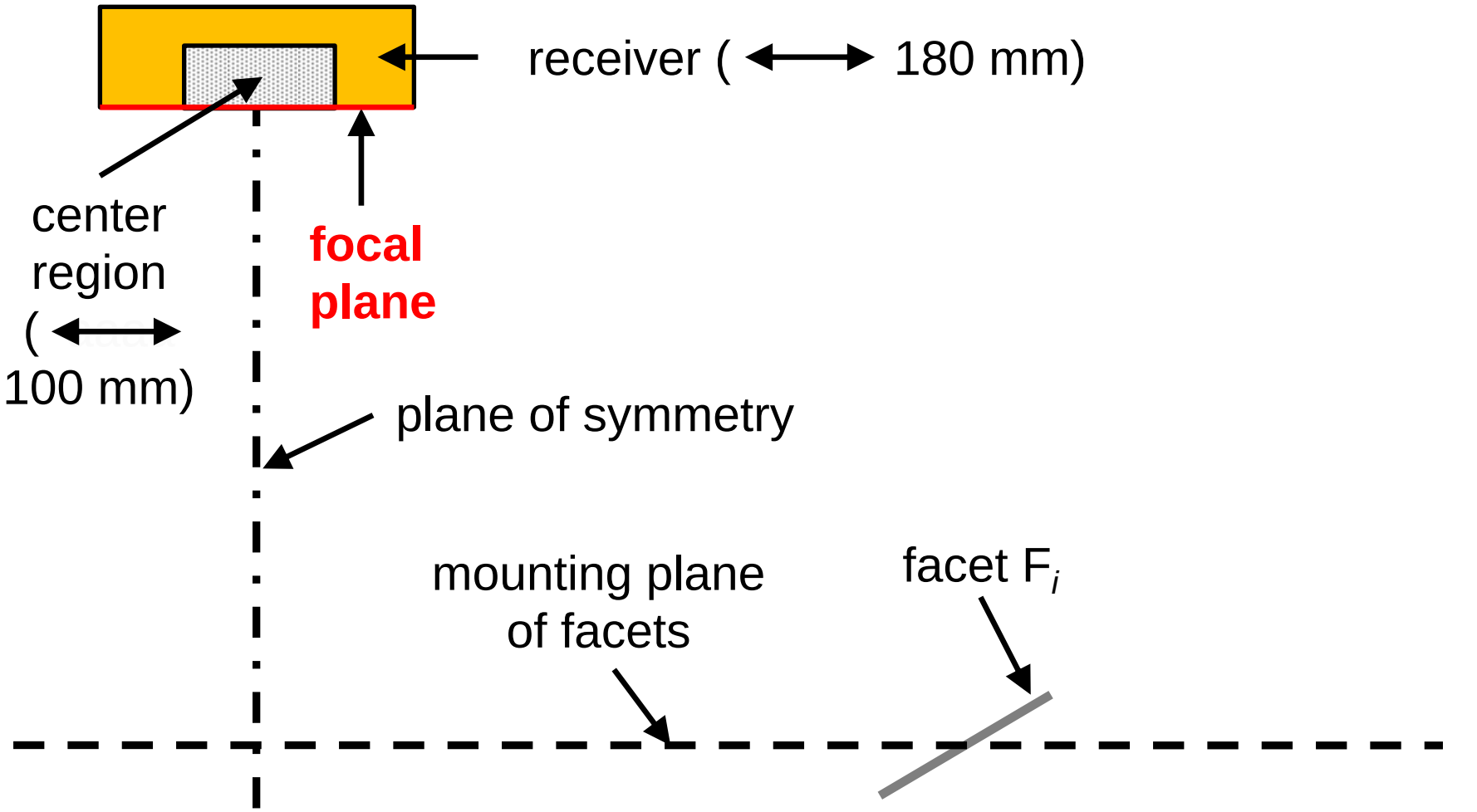
Improved

Modified Linear Fresnel Concentrator

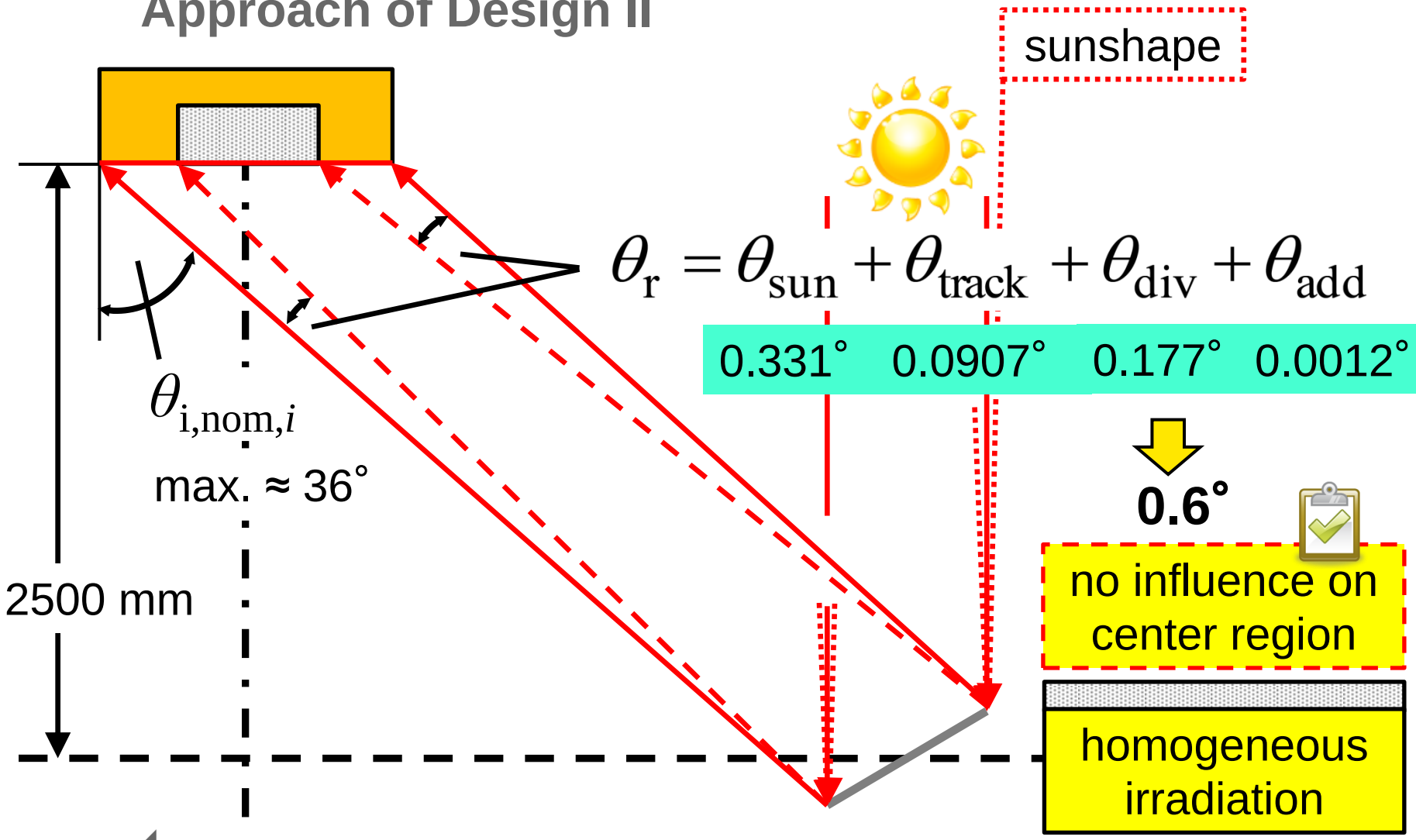




Approach of Design I



Approach of Design II

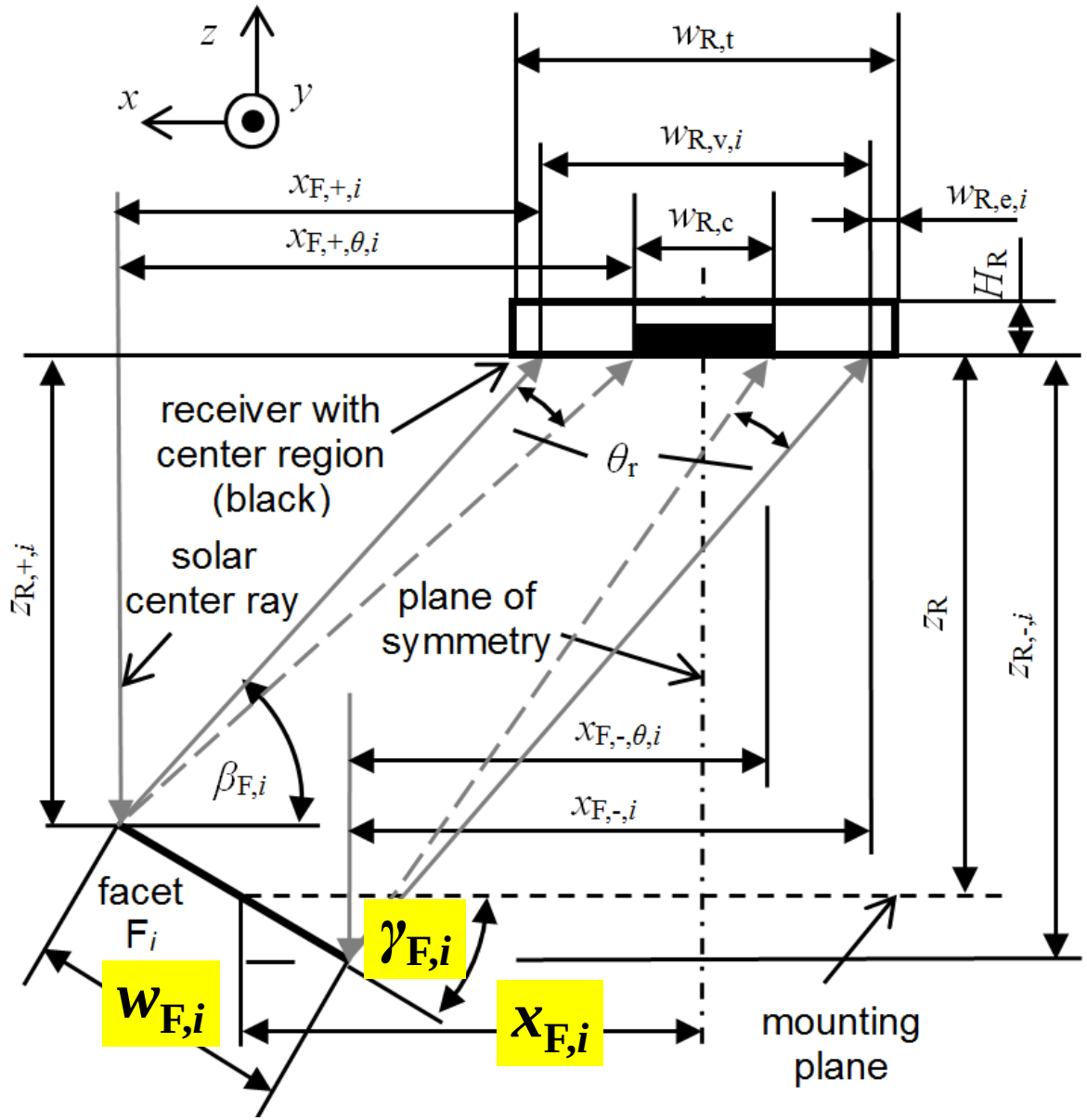


Approach of Design III

Defining facet dimensions
- facet width
- inclination angle
- nominal center distance

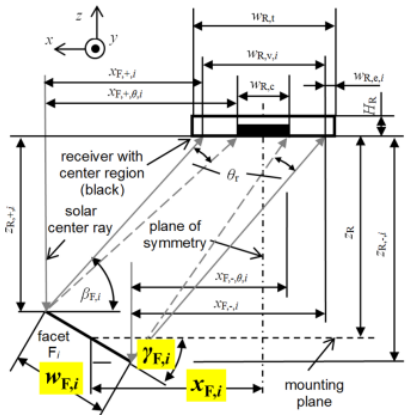
No shading!
- Facet / Facet
- Facet / Receiver

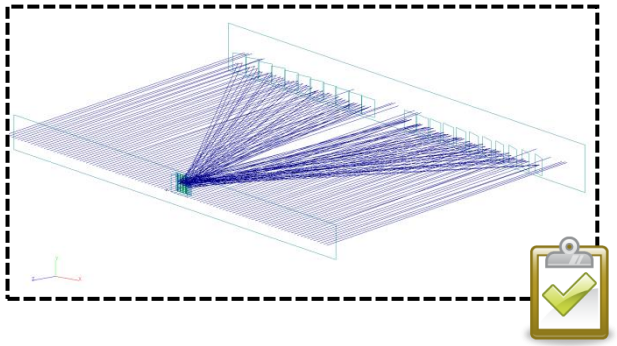
Width of facets
1st 152.1 … 153.3 mm
2nd **153.4 mm** fixed



Final Dimensions of the Concentrator Facets

Facet No. i	$w_{F,i}$ in mm	$\gamma_{F,i}$ in °	$x_{F,i}$ in mm
1	153.4	2.166	189.4
2		3.958	347.6
3		5.714	505.4
4		7.433	663.6
5		9.120	823.9
6		10.770	986.8
7		12.376	1152.6
8		13.934	1321.9
9		15.441	1495.1
10		16.893	1672.7
11		18.288	1855.0





C = 20.25 **$\theta_{i,nom,max}$ = 36.6°** **tracking error of 0.2° acceptable**

Solar Concentrator with a Rectangular Flat Focus

SoCRatus

white target in focal plane

- length of facets: 2654 mm
- aperture area: 8.8 m^2
- mirror material: Solar Surface® 992 provided by Constellium
- ρ_{SWH}: 87%
- $\rho_{H,UV\text{-}B/UV\text{-}A} > 80\%$
- tracking accuracy better than 0.1°

SoCRatus: Means of Qualification I

Visual inspection of illumination in focal plane

East (relative to front in south position) West

- “wave structure” in longitudinal direction
- comparably low deviations in cross direction

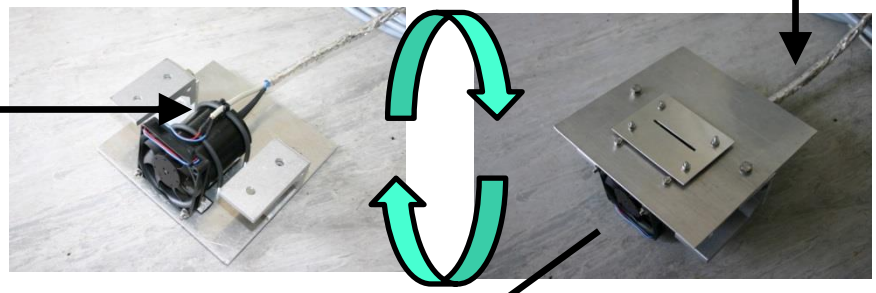
SoCRatus: Means of Qualification II

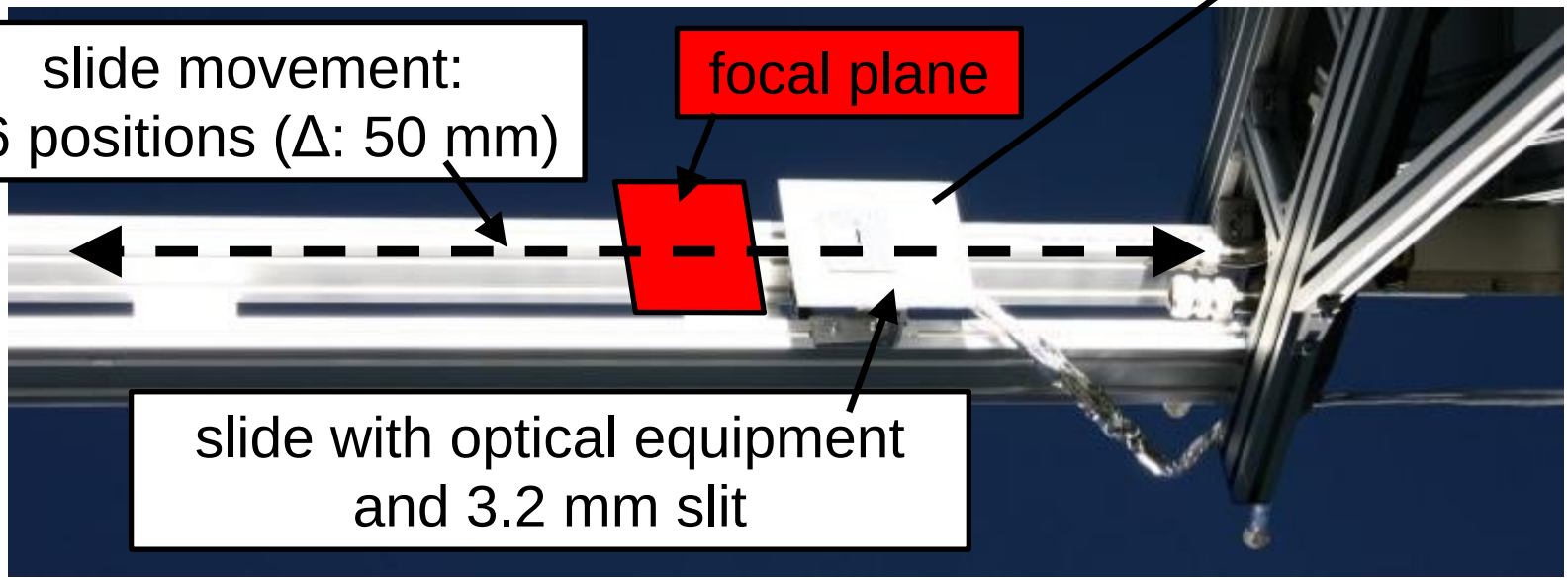
fiber optics to spectrometer B&W Tek Exemplar® LS

Detailed investigation in longitudinal direction

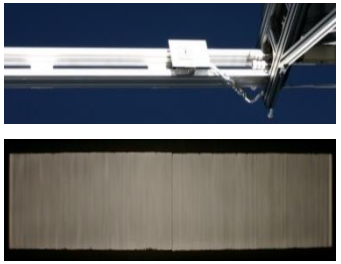
cosine inlet optics BIS-1.5

λ = 250 nm … 850 nm

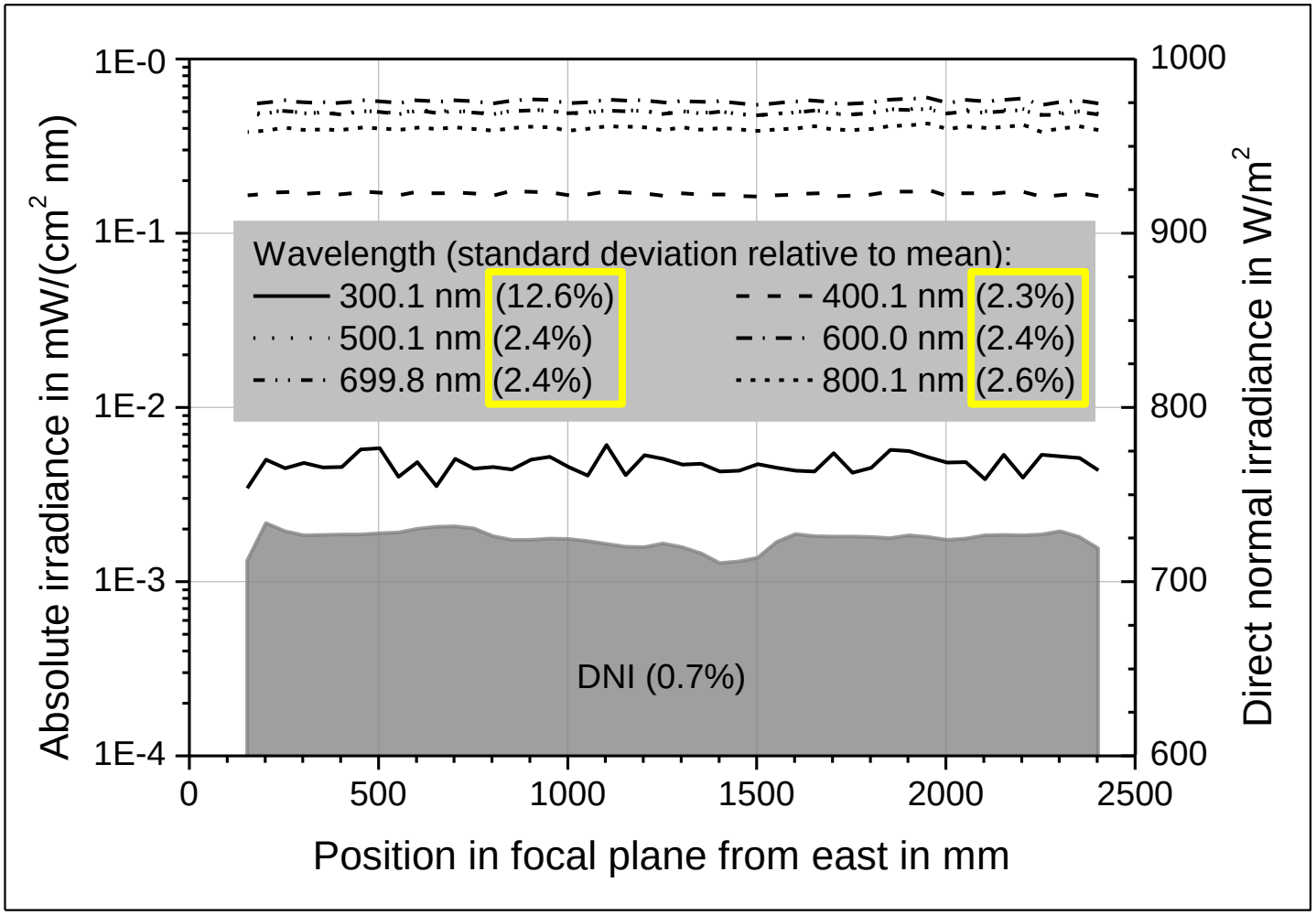




SoCRatus: Results of the Slide Experiments



$\sigma_{irr,rel} \approx 2.4\%$



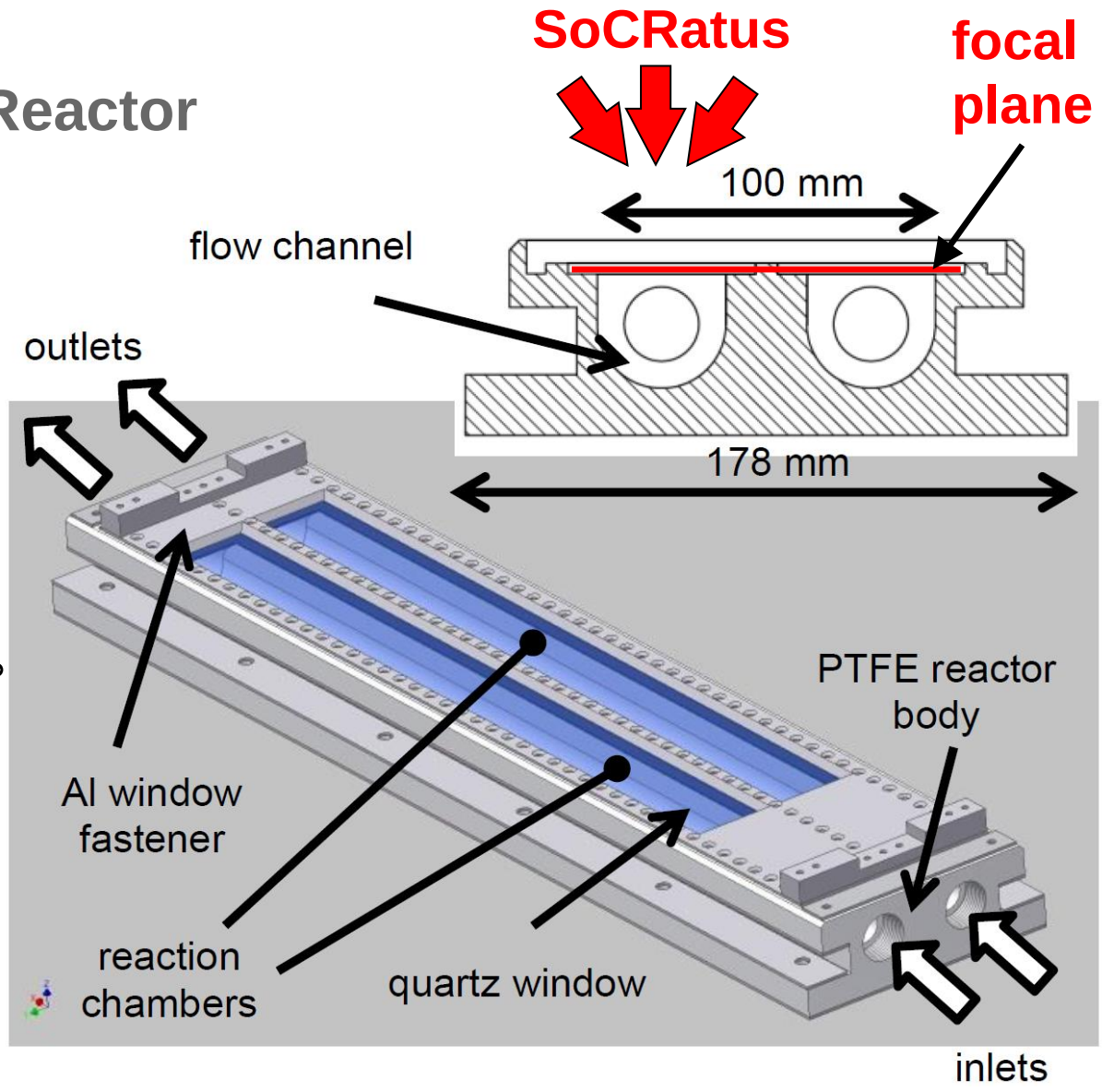
Suspension Reactor

PTFE reactor body

- chemically resistant
- low friction
- fairly reflective
- length: 750 mm
- inlet/outlet: shape of cones with half angles of 7.5˚and 20˚

Quartz window

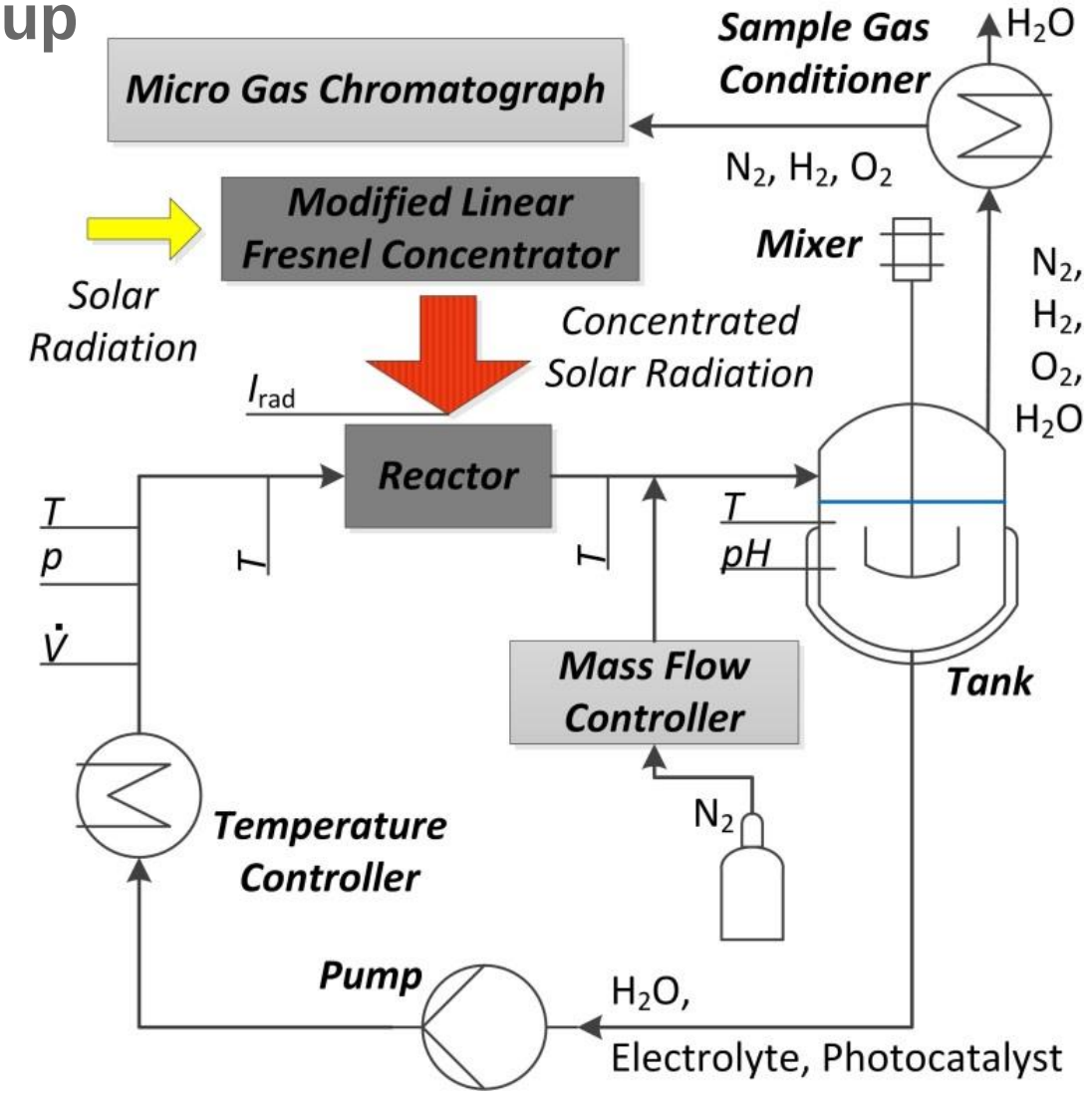
- transparent
- effective area: 196.5 cm^2



Experimental Set-up

Suspension
- deionized water
- electrolytes (H_2SO_4, NaOH)
- photocatalyst particles
- sacrificial reagents (methanol)

4 identical fluid cycles available



Experimental Conditions in Fluid Cycle 1 (03/13/2014)

- Photocatalyst: $SnNb_2O_6$ + Pt
- Electrolyte: H_2SO_4
- Sacrificial reagent: methanol

$c_{photocatalyst}$ = 2.1 g/l

pH = 4.0

$c_{methanol}$ = 10 vol.-%

$T_{average}$ = 59.3° C

$\dot{V}_{N,N2}$ = 1 Nl/min

$Re_{reactor} \approx 20000$

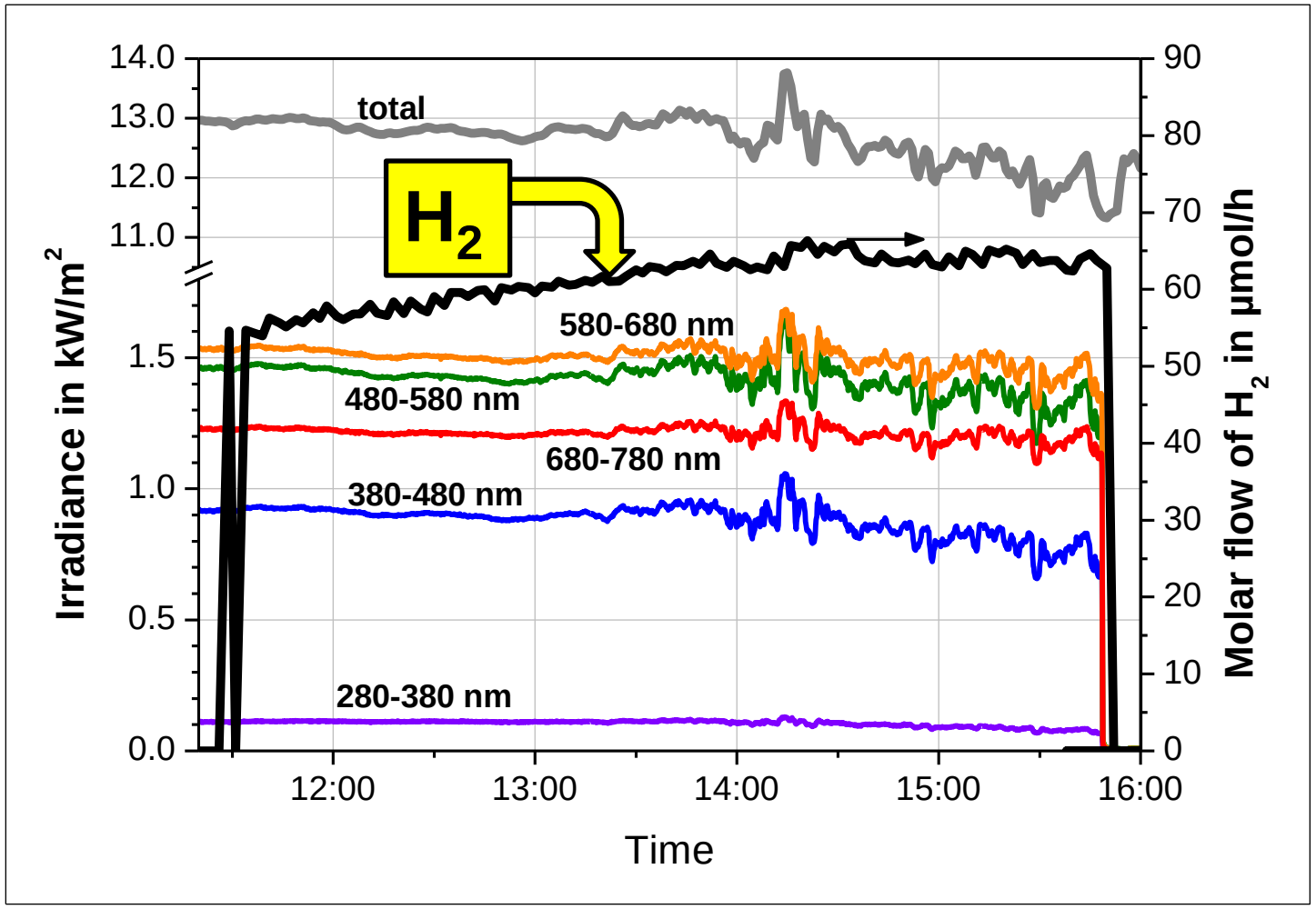
Experimental Results for Fluid Cycle 1 (03/13/2014)

Solar-to-hydrogen efficiency

$\eta_{opt} \approx 40\%$

0.00064%

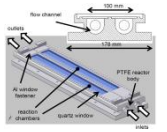
chemical system
total 0.0017%
UV-Vis 0.0041%
UV 0.20%



Summary and Outlook

- Solar Concentrator with a Rectangular Flat Focus (SoCRatus)
  - geometric concentration ratio: 20.2
  - rectangular flat focus: 2500 mm x 100 mm

- Suspension reactor
  - two parallel reaction chambers
  - flow efficient inlets and outlets



- First experiments in the field of photocatalytic water splitting for hydrogen production with methanol as sacrificial reagent
  - operation for several weeks
  - $SnNb_2O_6$ + Pt shows low efficiency

- Test facility will be employed in diverse projects and is available for further application

Acknowledgments

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